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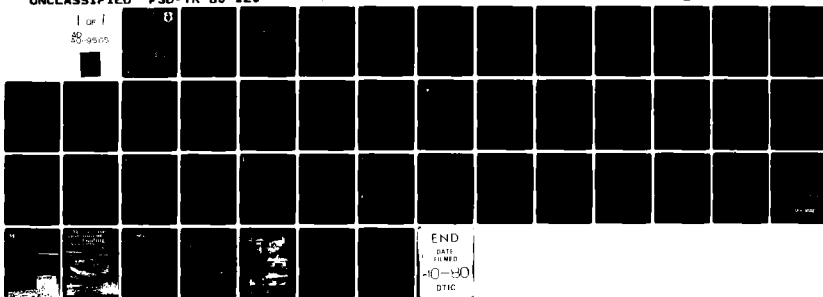
ELECTRONIC SYSTEMS DIV HANSCOM AFB MA
FEASIBILITY OF HELICOPTER SUPPORT SEEK FROST.(U)
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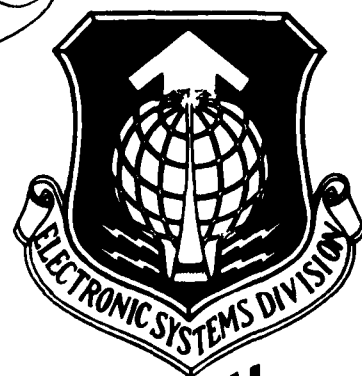
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Prepared for

DEPUTY FOR SURVEILLANCE AND CONTROL SYSTEMS
NORTH AMERICAN AIRSPACE SURVEILLANCE
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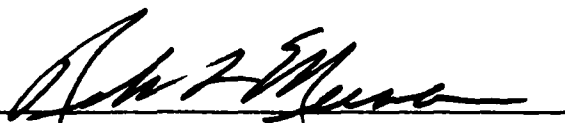
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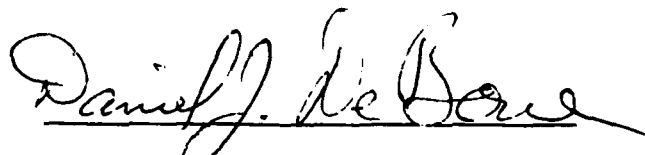
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REVIEW AND APPROVAL

This technical report has been reviewed and is approved for publication.



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A study supporting the feasibility of using helicopters for logistics support of minimumly and unattended radar stations in the northern areas of North America.		

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SECTION I: PURPOSE

The purpose of this study is to assess the feasibility of supporting the Seek Frost unattended and minimally attended radar sites by helicopter. This paper reviews the navigation systems, facilities, ground support equipment and airborne installed equipment that would ensure a high reliability and capability of the Seek Frost Support Helicopter. Field trips were made to major civilian helicopter companies to incorporate their world wide experience in helicopter operations into the design concept.

Present, in place equipment along the Dew Line is not addressed.

SECTION II: BACKGROUND

The helicopter supportability concept required in-depth research to assess feasibility. The Seek Frost Program Logistics Officer, Major Robert L. Merna, conducted the review to assess supportability of utilizing helicopters. Major Merna was selected primarily because he is fixed wing and helicopter rated and had seven years experience working in the Arctic environment. Mr. Max Levine of the Seek Frost Engineering Staff also assisted on the report and provided technical expertise on the program.

SECTION III: MAINTENANCE AND SUPPORT CONCEPT

Maintenance Concept - Based on the Unattended (UAR) and Minimally Attended (MAR) Station studies, the maintenance of the EDEW Line would be controlled and conducted from six main stations, which include facilities to support and shelter equipment and personnel necessary for the maintenance and logistics requirement of the line. The main stations are to be collocated at six of the thirteen MAR stations. The six stations concept was based primarily on the need for easy access to the unattended radar sites and the use of helicopters to facilitate that access. The advantages of using helicopters, rather than fixed wing aircraft, are many. Lack of personnel at UARs would preclude use of runways for a major portion of the year. The unrefueled range of a medium size helicopter limits maintenance segment sizes to approximately 500 miles. The six station configuration was chosen because of weather constraints and reduced risks. However, the final number and configuration of main stations will be determined during the full scale engineering development phase when contractor systems designs will be completed.

Support Concept - The support concept of Seek Frost required investigation of all type helicopters using performance and cost as the basic criteria. It was apparent during the initial stages that larger helicopters would be necessary to satisfy the range requirement. The following criteria was given to the commercial helicopter companies (Attachments 1, 2, 3) during TDY visits:

Main Site - Strip alert 24 hr.
- Helicopter hangared.

Capabilities - Twin Engine Self-starting @ -40°F.
- Maintenance Field Capable.
- Range 500 nautical miles unrefueled.
- Passengers 5.
- Cargo 2,000 lbs.
- Instrument certified.
- Equipped to maintain radio contact with main base.
- Avionics package.

Added Consideration: Door Dimensions for Cargo Compatibility

Maximum Height - 4'.
Maximum Width - 3'.
Maximum Depth - 4'.

Fuel cache at all sites to provide emergency aircraft refueling.
Note: Passenger weight 180 lbs plus Arctic gear equals 220 lbs.

SECTION IV: HELICOPTER CONSIDERATIONS

The critical performance factor was the 500 nautical mile range. All of the small utility helicopters are designed for transportation within 100 miles of the base station or commercial airport. They operate in VFR conditions and have one pilot. The light to medium helicopters, although having the increased capability of IFR and increased range to 300 miles could not satisfy the total Seek Frost requirements. Only those helicopters that could service the most distant site and return to the main station unrefueled were considered. The following helicopters were identified as candidates: (Attachment 4).

- Sikorsky H-53 (Military)
- Sikorsky H-3, S-61 (Military-Civilian)
- Sikorsky S-76 (Civilian-New Production)
- Sikorsky H-60 Uttas (Conceptual) (Military)
- Puma SA-330 (Civilian)
- Boeing Vertol H-47 (Military-Civilian)

Fuel Requirements - Type fuel will be aviation jet as all aircraft have jet engines. Quantity will vary dependent on type aircraft that will be utilized. All stations will have fuel available for emergency helicopter use. Minimally attended stations should have more fuel storage available for routine refueling. Ground power and heat must be available at the MAR should mission aircraft require extended ground time due to weather delays or overnight stays.

Range - Range criteria must be measured by worst case. The logistics nodes support stations as distant as 250 miles. This equates to flying from Boston to Baltimore and return. The remoteness of the area, limited weather reporting stations plus the urgency of the mission will require the helicopters to fly under instrument flight conditions. Aircraft are required to have an alternate field identified in the flight plan. Should the weather at the main station deteriorate to the point that the aircraft must go to its alternate field, fuel for the normal flight plus that required for travel to the alternate field plus a reserve for unknown contingencies must be available. Only the larger type helicopters have the flexibility to support the distances required in the Seek Frost System.

All the candidate helicopters are capable of meeting and exceeding the 500 nautical mile mission range. Helicopters have the following limitations when range and useful payload are considered: Weight criteria becomes an important variable. The following is a brief synopsis on helicopter weight variables.

Basic Weight - No crew, no fuel and oil, and no mission equipment.

Empty Weight - No crew, no fuel and oil.

Maximum Weight - Weight at which the helicopter can complete its mission. This takes into account the altitude that the helicopter must land at. Ambient air temperatures are very critical. Higher

temperatures are more critical on aircraft performance. Single engine operations must be considered on maximum weight. Maximum weight increases when operating at colder temperatures and at sea level. The aircraft engines may be able to exceed the design maximum weight. Therefore, all aircraft have a "do not exceed" maximum gross weight regardless of engine capabilities.

Payload - The distance that the aircraft will have to transverse determines the fuel requirement. The basic weight, plus the crew, plus the oil and fuel plus the mission equipment weight and the allowable maximum weight can be used as the payload. The payload is a variable. Small helicopters with full fuel and auxillary tanks can fly extended distances but, are unable to carry a useful payload. The candidate helicopters have the flexibility of meeting Seek Frost mission requirements. Should sites require large replacement units, the selected helicopters would be able to provide the airlift and would require fewer refueling stops enroute to the most distant station.

Helipad Requirements -

Unattended Station - Helipad - The size of the helipad must be large enough to support existing DOD helicopters should defense conditions or rescue operations dictate the site be used as an operating location.

The helipad should be elevated above the surrounding terrain to assure the pad is wind swept clear.

Approach and ground lighting must be available during poor visibility, whiteout conditions, and night operations to assist the pilot in the final phase of landing. Tie-down capability must be available to secure the helicopter during high winds or if the helicopter must remain at the station due to maintenance.

Helipad Dimensions - Seventy by seventy (70 x 70) will be adequate to land an H-53. The weight bearing capacity of the pad must be capable of supporting 70,000 lbs three point twin wheel configuration of the H-53. Markings of the pad will be in accordance with FAA AC 150/5390-1B. An abbreviated visual approach slope indicator system is needed to assist the pilot in his final approach. Darkness exists six months out of the year. High intensity approach lighting will be required to assist the pilot in positioning the aircraft in the landing environment.

Refueling - The unattended station will require piping from the fuel storage area to the helipad. The system could be designed for a portable pump, that the helicopter will carry, to be attached and provide positive pressure to the system nozzle, for rapid refueling of the helicopter. The system should have this capability because of the limited power available at the site. Secondary consideration is that the refueling may have to be done without aid from the site power source.

Weather - Because of the extended area that the Seek Frost System covers the weather is classified into four zones (Attachment 5):

- Zone 1 - Alaska Coast. 1 MAR 6 UAR
- Zone 2 - Yukon Coast to MacKenzie River. 1 MAR 3 UAR
- Zone 3 - MacKenzie River to west of Cape Dyer Northwest Territory. 6 MAR 23 UAR
- Zone 4 - Eastern Coast from Cape Dyer Northwest Territory to southern Labrador. 4 MAR 4 UAR

The western three zones are unique and could be classified as deserts. The precipitation is very slight, while in the eastern zone (zone 4), the precipitation can reach as much as 200 inches on an annual basis. During the summer and autumn the worst conditions will occur in zone 4 from the standpoint of low ceilings and fog. This is due to warm, moist air in close proximity to cold water and melting ice. Zone 4 with the combination of mountainous terrain and increased possibility of IFR flying conditions is the most challenging area. To maintain the reliability of helicopter support all flights must be planned for instrument flight conditions.

Visual Flight Conditions - Because of the unique characteristics of the helicopter it is capable of flying under visual flight rules when fixed wing aircraft are required to file instrument flight rules. There are many combinations of ceilings and visibility that equate to VFR conditions and rather than review all of these, it is apparent that, excluding maintenance and administrative delays, the helicopter will be able to perform the assigned mission when VFR conditions exist.

Instrument Flight Conditions - Reliability in air transportation requires the helicopter to fly in all types of weather. As with all aircraft, there are limiting factors that affect instrument flying. Icing, turbulence, thunderstorms, take off and landing visibility are a few. British Airways Helicopters has been operating a scheduled IFR service between the Isles of Scilly and Penzance in the southwest area of England with Sikorsky S-61 Helicopters since 1972. Evergreen Helicopters provided IFR helicopter service from Yakutat, Alaska to exploratory drilling platforms in the Gulf of Alaska from 1974-1975. The present oil exploration in the North Sea is supported by IFR certified helicopters. This area and the Gulf of Alaska have some of the worst flying weather in the world. The state-of-the-art in helicopter operations is that IFR flying is a routine practice. All aircraft are restricted from flight in some forms of icing (Attachment F). At present, U.S. helicopters are restricted from flying in icing conditions. The French built Puma, a large size helicopter comparable to the Sikorsky S-61, has been certified to fly in icing conditions by the French Government. Petroleum Helicopters, Inc., has been working with FAA to certify and clarify icing limitations on this helicopter. Military tests are conducted on all aircraft concerning cold weather testing that included aircraft flight characteristics in icing. Icing is a condition that occurs when visible moisture is present and the free air temperature is in the approximate freezing zone. The accumulations of icing on the rotor blades affects the aerodynamic capabilities and requires increased power to overcome the deficiency. Due to the rotating

surface the ice accumulation separates from the blades by centrifical force and causes an unbalanced condition throughout the entire rotor system. This affects control and induces low frequency vibration throughout the helicopter. Ice shedding from the rotor blades has caused structural damage and damage to engines by injestion. The serious threat to the helicopter pilot when operating in icing conditions is that the shedding ice could impact adjacent blades causing structural failure and loss of control.

As with all Arctic operations extreme low temperatures require personnel and equipment work limits for safety reasons. At -40°F , military station supervisors usually restrict personnel from routine outside work. At -45°F emergency essential work is cleared through higher level supervisory personnel. At -60°F all outside work ceases and vehicle use is discontinued. Aircraft were impacted because of refueling requirements and cargo on and off loading. Rotor wash from helicopters at sub-zero temperatures is very dangerous due to the extreme chill factors that are created. In the Alaskan Air Command routine flight missions are cancelled when the site temperatures are below -45°F . With a fully qualified crew and technicians temperature limits can be modified for flights to unattended radar stations. These extreme temperatures are not consistent for long periods. Extreme low temperature normally exist for only two to five days. Average mean temperatures in the winter months would be approximately -25°F for the Seek Frost System.

Navigation Aids - The most important feature of helicopter supportability is the navigation equipment that will be needed to achieve the helicopter reliability. Adequate navigation and approach aids must be available to ensure responsiveness of airlift. The 20 year life system cannot be supported with less than the following considerations on comparable equipment.

Main Station (Logistics Nodes) - The main station is the main base for the attended and unattended stations. Helicopter support will stage from the main station. Runways will be at all logistics nodes for lateral supply of rations, spares and transfer of personnel. Complete enroute and terminal aid packages must be installed. The following equipment is required to ensure airlift reliability at the main station.

Airfield - Airfield Lighting meeting existing
FAA/MOT standards.

- High intensity approach lights.
- Instrument landing system.
- VORTAC.
- ADF.

Radios - VHF/UHF/HF.
- Beacon transponder.

Minimally Attended Stations

- Beacon transponder.
- Microwave landing system (Atch 6).
- VHF/UHF/HF.
- High intensity lights.
- Helipad lighting.
- Complete weather package including barometric pressure.

Unattended Radar Stations

- Abbreviated Visual Approach Slope Indicator System (AVASI).
- High intensity lights.
- Beacon transponder.
- Weather telemetry - Ceiling, visibility, temperature, dewpoint, winds, barometric pressure.
- Helipad lighting.

Cargo payloads - The Seek Frost System requires the transportation of technicians tools and spares to the MAR or UAR station. Average payloads would consist of:

2 Technicians	440 lbs
Tool Boxes	100 lbs
Spares	100 lbs
Aircraft Support	
Equipment	250 lbs
Survival Kit	200 lbs
	<u>1090 lbs</u>

Special design consideration must be given to the cargo compartment to simplify equipment handling. The helicopter should have a mini-fix-it shop capability. Large equipment replacement will be handled in much the same way. Handling capabilities will require designs for removal from the helicopter such as by an on board hoist or ground type means to move the equipment to the unattended station. Over-sized cargo can be carried by cargo sling. Airspeeds must be reduced due to the aerodynamic qualities of the cargo. Ground handling equipment must be pre-positioned to support these cargo sling requirements. The MTBF of the Seek Frost System will be complimented by the vertical airlift support. (Attachment 7).

Fuels Transfer - The unattended sites will require only bulk petroleum products. Using the helicopter for transfer of the cargo from resupply ships to the site will be a simple logistics task. Depending on the optimum load of each trip, and amount of fuel to be transported will determine the time involved. Let's take a sample case. UAR station 27 requires 16,000 gallons of fuel for the summer resupply. The petroleum could be in 55 gallon drums, 500 gallon fuel bladders or because of the system design, assume special 5,000 lb metal drums were built for this operation. Five thousand lbs of fuel equals 893 gallons. The candidate helicopters have cargo sling capacities of 8,000 lbs, but for safety reasons, the 5,000 lbs limit was set. To move 16,000 gallons the helicopter will have to make about 18 trips. Time factors are five minutes to hook-up at each location (ship and site) and five miles enroute or five minutes.

The crews could start at 8 am, have a coffee break at 1000 and refuel the helicopter. Break for lunch at 1215, back to work at 1300 and have a completely resupplied site by 1500. Personnel involved would be the helicopter crew, a hook-up man at both pickup and discharge points and two personnel to transfer fuel to the storage tank and act as safety observers. This concept would minimize ground handling and favorably impact on the ecology. This type operation is routine in field operations. If resupply ships could be positioned at each main station, the entire line of unattended stations could be restocked in two weeks. The resupply limiting factors would be aircrews and weather because there is no darkness in the summer.

Aircraft Avionics Requirements - To improve reliability the following on board avionic equipment are required:

- VHF/UHF/HF (A DF capability on one radio would be advantageous.).
- Radar altimeter.
- ADF receiver.
- VOR/ILS receiver (with MLS mode).
- Beacon transponder.
- Weather radar with beacon mode.
- Distance Measuring Equipment.

Radios are required for the following reasons:

VHF radio frequencies are primarily utilized by civilian aircraft and the capability will be required in the Seek Frost System.

UHF radio frequencies have been used primarily by military and helicopters should have a capability to converse with military aircraft should the need arise.

HF radios have a far greater range and do not depend on line at sight transmission as do the VHF and UHF radios. Should the support helicopter be required to make a remote landing away from the Seek Frost stations, the HF capability will enable communications with the logistics node to ask for assistance or maintain radio contact.

Navigation receivers are necessary to compliment the IFR capability.

Weather Radar with Beacon Mode will further enhance the reliability of helicopters to complete the assigned mission.

Radar altimeter provides a positive height above the ground and is a valuable aid during white-out conditions and for instrument approaches.

SECTION V: SUMMARY

Of the candidate helicopters the H-60 Uttas is in the engineering and development stage. The S-76 has only been operational in the commercial market a short period. All new equipment undergo modifications after several years of operational experience. System life changes and limits on sub-systems are constantly changed after field experience. Equipment with proven reliability should be identified.

Non-completion of missions usually occur due to enroute conditions. Past experience in helicopters has been that they were required because the mission was to a remote, bare base. Visual flight rules had to be maintained throughout the flight envelope because there were no navigation aids enroute to transition from IFR to VFR conditions and reach the bare base. As navigational aids were improved, and helicopters were equipped with augmented stability systems, flying in clouds became routine - not an emergency measure.

British Airways scheduled helicopter service has been able to maintain a 98% reliability. Seasonal weather conditions could be planned into the Seek Frost maintenance concept. Complete navigation aids on the ground as well as on board the helicopter will increase the reliability of the system. The Seek Frost System is designed for a 20 year life. The support planning for logistics helicopters must be considered up front for that reliability. Current rental cost of heavy life aircraft are generally \$100,000 per month plus \$300-500 per flying hour. Due to the remoteness of the logistics nodes a backup helicopter would seem necessary at each node. The second (possibly smaller) helicopter could be utilized to support closer unattended stations. The operating cost would be approximately 50% less for a Bell 212 or comparable type. As the system overcomes its growing pains, strategic locations of the heavy lift helicopter could be changed to support the maintenance schedule. Initial planning must consider worst case. As firm requirements and proven reliability of the design concept are verified, helicopter requirements may be reduced. Present investigation identifies two helicopters per logistics node or a total of 12. For ease of maintenance support, the type should be standardized. Military versus contractor raises several points. Costs, although difficult to measure, appear to be less if all helicopters were contracted from private industry. A total military helicopter capability would be more expensive and manpower intensive considering the support techniques unique to military operations. Canadian Air Force Helicopters do maintain a 1,000 mile ferry capability and could satisfy all military requirements in support of the Dew Line.

SECTION VI: RECOMMENDATIONS

Helicopter support is feasible and the current state-of-the-art in commercial IFR helicopter operations, indicates the Seek Frost support concept would be a normal operation. Complete design for a first class navigation package is essential to provide reliable, highly available helicopter logistics support.

Recommend the following consideration be incorporated in the Seek Frost contract requirements:

Helicopter - A proven helicopter of the S-61 type could best support the system with the following on board equipment:

- Radios UHF/VHF/HF (DF capability).
- Weather radar with beacon mode.
- Radar altimeter.
- Portable pump for refueling, from unattended sites.
- Modified ILS equipment to accept and decode the microwave landing system.
- Special designed equipment rack for site support.
- Special material handling equipment available for larger spares.

Ground Support - The following ground support equipment is recommended to insure maximum reliability to the system:

Attended Stations - One logistics node should be located on Greenland for reliable support to Greenland sites.

- Support Equipment - Capability to refuel aircraft, ground heaters.
- Navigation Aids
 - Let down navigation aid.
 - Microwave landing system. (Attachment H).
 - High intensity approach lights.
 - Beacon transponders.
 - UHF/VHF/HF radios.

Unattended Stations

- Let down navigation aid.
- AVASI.
- High intensity lights.
- Helipad lighting.
- Helipad dimensions 70' x 70'.
- Point refueling at pad.
- Beacon transponder.
- Raised helipad.
- The helipad designed for approach into prevailing wind.

PETROLEUM

HELICOPTERS

INC.

POST OFFICE BOX T

PHONE (318) 235-2453

LAFAYETTE, LA. 70502

March 7, 1979

ESP/OCUL Attention Major Merna
Hanscom Air Force Base
Massachusetts 01731

Dear Sir:

We enjoyed meeting you and Mr. Max Levine and your briefing on "Seek Frost" given to us on 6 March 1979.

Petroleum Helicopters has been involved in logistical support by helicopters in remote areas for many years and agrees that your concept of on site support for radar sites is a practical objective.

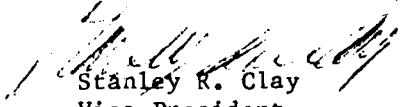
In our opinion it would be important for the support helicopters and crews to be instrument qualified and to develop special procedures for instrument approaches at each site. Also we believe that it is important when designing instrument approaches at remote areas to provide as much of the guidance as possible on board the helicopter to reduce the complexity and cost of ground units as much as possible and increase the reliability. For example - airborne radar approaches using natural features along with radar reflectors or radar beacons.

The airborne equipment we have been using successfully for many years includes:

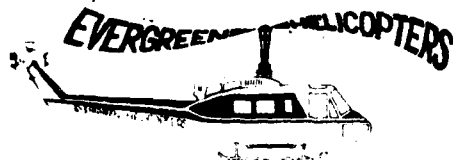
- 2 VOR/ILS Receivers
- 2 VHF Transceivers
- 1 ADF
- 1 75 MHZ Marker Beacon Receiver
- 1 DME
- 1 Transponder
- 1 Weather/Mapping Radar
- 1 Omega/VLF Navigator, or Loran "C" Navigator depending on the area of operation.

If we can be of any assistance please let us know.

Very truly yours,
PETROLEUM HELICOPTERS, INC.


Stanley R. Clay
Vice President
Chief Pilot

SRC:abl



April 10, 1979

Major Merna
ESD-OCUL
Hanscom AFB
Massachusetts 01731

Dear Major Merna:

Thank you for taking time from your busy schedule to visit our Corporate Headquarters in McMinnville, Oregon recently.

We are deeply grateful for the opportunity to have met with you and Mr. Levine, and to receive your well prepared presentation on the SEG-FROST program.

As presented, we foresee the eventual support of such a system by helicopter as being entirely feasible. Evergreen Helicopters of Alaska, Inc., has an extensive history in the Arctic region and has previously performed similar tasks to those mentioned in the presentation.

In 1976, for example, Evergreen Helicopters of Alaska, Inc., became the first FAR 135.2 certified carrier operating under instrument conditions in the United States, while supporting drilling activities in the Gulf of Alaska. During this period, three S-61N helicopters were fully IFR instrumented for all weather, day and night support capability. A three level navigation system of ADF, tacan and radar provided multiple reliability and permitted approaches down to two hundred foot ceilings and one half mile visibility. VLF Global Navigation 500's supplied location information to within one tenth of a mile. In 1977 alone, our S-61's carried 10,777 passengers and 1,141,827 pounds of cargo between offshore drilling rigs, and bases at Yakutat and Cape Yakataga, with an average maintenance availability of 94.8%. In spite of harsh climatic conditions, only 1.26% of the total flights were delayed due to weather.

One again, I'd like to express our thanks to you for meeting with us. We appreciate being informed of your expected support needs and hope we may have the opportunity to participate in the program.

Sincerely,

EVERGREEN HELICOPTERS OF ALASKA, INC.


Peter E. Hadley
Marketing Representative



OKANAGAN HELICOPTERS LTD.

4991 AGAR DRIVE, RICHMOND, B.C. V7B 1A5
TELEPHONE (604) 278-5502 TELEFAX (604) 355-5594

May 15, 1979

Major R. Merna
ESD/OCVL
Hanscom Air Force Base
Massachusetts, 01731

Dear Major Merna:

Re: Seek Frost

We appreciated the opportunity to meet with you and Mr. Max Levine on the 6th and 7th of this month. In our view we received sufficient information to appraise the feasibility of using helicopters as lateral support between locations on the line.

Under the general terms of reference outlined and discussed we regard the use of helicopters in this function as a straight forward application. Our past and current work activity has required solutions to the type of problems foreseen. Basically, we feel the support mission you envisage can be handled as a routine assignment. Very little "pioneering" would be encountered should the prospect materialize.

Further to company background information already submitted to yourself and Mr. Levine, we have enclosed a copy of the 1977-78 Annual Report. Okanagan is a public company listed on the Vancouver and Toronto stock exchanges.

Although we have concentrated market activities in recent years on offshore markets, it has not been at the expense of high arctic service. At this writing we are operating a Bell 205 at the North Pole in support of ice drift studies.

We hope we have been able to provide you with the information you require, but please do not hesitate to advise us if further data would be helpful.

Yours very truly,

OKANAGAN HELICOPTERS LTD.

Kyle W. Steele
Special Services
Marketing Manager

HELICOPTER CANDIDATES APRIL 1979

MANUFACTURER MILITARY DESIGNATION COMMERCIAL DESIGNATION	MAX AIR SPEED CRUISE	PASSENGER	PAYLOAD	RANGE	IFR CERTIFIED	COST PER HOUR	ENGINES	AMPHIBIOUS
Sikorsky H-53	165 130	55	32,000	450+	Mil	M\$900+	2	No
Sikorsky H-3 S-61	130 120	22	6,500	430+	Yes	M\$600+ C\$1000	2	Yes
Sikorsky S-76	156 125	12	4,500	600+	Yes	C\$280	2	No
Sikorsky H-60 UHRS	153 145	15	6,500	400+	No	Unk	2	No
Puma SA-330 J	155 140	18	4,200	400+	Yes	C\$1000	2	No
Boeing Vertol H-47 B/KV 107	175 150	33	28,000	450+	Yes	M\$1205 C\$2081	2	Yes

Climatic Description for SEEK FROST System

1. INTRODUCTION

The SEEK FROST program will be installing a line of surveillance radars from northwestern Alaska, across northern Canada to eastern Baffin Island and down the coast of Newfoundland. The line spans the entire continent of North America and will be constructed in at least four climatic regions.

Table I summarizes the geographic areas which can be described from a climatic point of view as nearly homogeneous regions. Such a description could be misleading since it tends to infer that the entire region experiences the same type of day-to-day weather. This is true only to the extent that broadly defined criteria are met. Only the mean occurrences of meteorological variables within the region are similar, while the short-term variations can produce a wide range of conditions.

2. GENERAL CLIMATIC DESCRIPTIONS

2.1 Zones 1, 2 and 3

The region spanned by the SEEK FROST program from the northwestern coast of Alaska to Cape Dyer is generally classified as a tundra climate. As such, the region experiences summer temperatures sufficiently above freezing to maintain vegetation consisting of moss, lichen and grasses.

A special feature of most of this area is the high degree of variability in the duration of incoming solar radiation. During the summer, when daylight can last as long as 24 hours, one might expect that temperatures should rise appreciably. However, clouds and the presence of ample amounts of snow and ice cause a large amount of the incoming radiation to be reflected back into space. Of the amount which is absorbed, the majority is utilized melting the ice, and, as a result, summertime temperatures remain cool. During the Arctic winter, large quantities of heat are radiated to space producing very cold temperatures and annual temperature variations exceeding 100 Fahrenheit degrees.

The low temperatures in the region cause low absolute humidities and, in general, sparse precipitation. The majority of precipitation occurs in the summer when the open ocean can provide a ready supply of moisture. Once the water freezes, the region is dominated by an intense, cold anticyclone which tends to inhibit precipitation. However, in spite of the low precipitation, the low evaporation and melting in some areas enables large snow fields to be maintained.

Mean cloudiness is quite variable in this area. The strong winter anticyclone produces generally clear skies while the summers are very cloudy. Large areas of stratus clouds and fog exist over the cold waters of the Arctic Ocean. In summer, portions of this region rank among the foggiest of the world.

2.2 Zone 4

Markedly different in climate from the other three zones, the section from Cape Dyer to the coast of Newfoundland experiences a cool, snow-forest climate with ample precipitation throughout the year. The majority of North American cyclone tracks pass through this region of Canada which helps to explain the precipitation amounts and distribution. These migratory cyclones continually reinforce the off-shore flow which keeps temperatures in the winter below those which would normally prevail at these latitudes.

Precipitation is distributed evenly throughout the seasons. The frequent storm passage and readily available moisture source produce annual precipitation totals as high as 52 inches. Snowfall occurs in large amounts with annual totals approaching 200 inches. The southern portion of this region is the only area along the entire line where thunderstorms (on a maximum of 5 days) can be expected to occur each year.

In this region, too, fog is a frequent occurrence. The Labrador Current around Newfoundland is instrumental in the production of fog and low clouds. Warm moist air from over the continent as well as from adjacent ocean waters produces fog as it passes over the cold water. The summer season is a period of fog maximum along the entire southeastern coast.

Of prime importance to the SEEK FROST program is the incidence of heavy icing and wind loading on structures in this region. The abundant precipitation and fog in the area results in ice accumulation as high as 3.3 inches.

3.0 Meteorological Parameters

3.1 Temperature

Table 2 contains data which reflect the range of temperatures, both monthly means and extremes, which will be encountered by the SEEK FROST program. While zones 2 and 3 have recorded the lowest temperatures, -62°F at Aklavik and -63°F at Cambridge Bay, zone 3 records the lowest monthly mean temperature, -39° in February. Below freezing temperatures are nearly a daily occurrence in zone 1 and daily sub-zero readings are observed for nearly half the year in all zones except in zone 4, where the maritime influence moderates the climate significantly.

Maximum temperatures only rarely exceed 90°F , and then only in zones 2 and 4. Goose Bay is the only location at which temperatures greater than 90°F are observed regularly, and, even there only four years of every five. The largest variation in the mean monthly temperatures occurs in zone 4 which contains locations with mean maximum temperatures in February as low as -14°F and others with means in July of 69°F . This variation is due in part by the north-south orientation of this zone and is not representative of the seasonal variation at a single location.

The greatest seasonal variation in mean monthly temperatures at given locations occurs in zones 2 and 3.

3.2 Precipitation

Table 3 contains maximum and minimum mean precipitation and snowfall data for the four climatic zones. In addition, the mean number of days on which precipitation \geq 0.1 inch, snowfall \geq 1.5 inch and thunderstorms occur appears. Precipitation data tend to be less available for these areas than are temperatures with the more remote locations under represented in climatologic summaries. Furthermore, precipitation, especially when frozen and driven by high winds is a difficult parameter to measure reliably. Hence, the figures in Table 3 represent more comparative indications than precise measures.

The most striking difference among the four zones with respect to precipitation is its absence in the first three zones and its relative abundance in zone 4. With the single exception of the region around Frobisher Bay, all locations in zone 4 exceed the highest value of mean annual precipitation observed in the other three zones. Precipitation in zone 4 averages four to five times that which occurs from Pt. Barrow, Alaska to Cape Dyer, NWT.

A similar condition exists with respect to snowfall. A slight overlap in yearly totals exists between areas around Clyde in zone 3 and Cape Hopes Advance in zone 4, otherwise snowfall in zone 4 everywhere exceeds the maximum observed in the other three areas. Of particular interest are the annual totals in the vicinity of Cartwright and Harrington Harbor which reach 200 inches on the average.

The differences in precipitation regimes between the first three zones and the fourth is demonstrated further when examining the number of days on which heavy precipitation occurs. Days with precipitation include those on which snow

falls. For example, in zone 1, a snowfall equal to or greater than 1.5 inches occurred on 8 of the 23 days during which precipitation equal to or greater than 0.1 inch was recorded. A comparison of these figures for all areas reveals that heavy precipitation, both rain and snow, occur on two to three times as many days in Zone 4.

Similarly, thunderstorms can be expected every year only in southern Labrador. On the average, a thunderstorm occurs on one day per year in zone 2, but the year-to-year variability is sufficient to produce years with no occurrence.

3.3 Flying Weather (Cloud cover and visibility)

Various combinations of cloud cover and visibility are defined as they affect aircraft operations. Two combinations are tabulated (Table 4) as representative of minimum and instrument flying conditions. Statistics are presented in the form of frequencies of occurrence of ceilings (clouds covering half or more of the sky) less than 1500 feet and/or visibilities less than 3 miles; and ceilings less than 300 feet and/or visibilities less than 1 mile. As was true with the precipitation data, the more restrictive condition (≤ 300 feet and/or 1 mile) is contained within the other.

The flying weather, due to its wide variability and geographic dependence, is extremely difficult to depict for each zone as a whole. The data are generally collected at locations which are easily accessible, which places most near the coast, and tends to oversample the distribution of fog throughout the whole area. On the other hand, most locations are at low elevation which tends to under sample fog and low ceiling statistics for elevated areas. The figures presented in Table 4 must be applied with the utmost care.

As previously mentioned, the summer and autumn at most places tend to be the worst seasons from the standpoint of low ceilings and fog occurrence. Warm, moist air in close proximity to cold water and melting ice form a favorable combination for just such conditions. At several locations, Cape Dyer in zone 3 and others in zone 2, autumn exceeds summer in the frequency of adverse flying weather. In zone 4, there are several stations with primary or secondary maximum in winter, reflecting the high snowfall and winter storm occurrence.

Cape Dyer in autumn is the location along the entire region which experiences the highest percentage of time with low ceilings and poor visibilities. Nearly half the time the ceiling is below 300 feet and/or the visibility below 1 mile at certain times of the day.

3.4 Wind and Ice Loading

Of particular interest to the designers of systems to be deployed in severe environments are the additional loads which will be placed on the structures due to winds or a combination of winds and ice accumulation. The SEEK FROST program will be faced with designing the system and its supporting structures in an environment which ranks among the most severe in the world when ice and wind loads are considered.

If winds are considered solely; climatic zone 4 and to a lesser degree zones 1 and 3 experience the most severe conditions (Table 5). Sustained winds in zone 4 of at least 150 knots and extreme gusts to 195 knots can be expected to occur at 30 feet above the surface at the one-percent risk level for a 20-year design lifetime. A sustained wind is generally taken to be that which occurs over a 5-minute period while the extreme gust is the maximum wind speed attained. These extreme values tend to occur at the locations with the highest elevations. However,

for these locations near sea level, the reduction in the extreme values is only about 20 percent.

A slightly different picture emerges when examining the expected loads on structures due to the combination of ice and wind. From Table 6 it is apparent that zone 4 again contains the most severe conditions. However, zone 3 experiences two-thirds as much ice loading as zone 4, while in zone 1 less than half that of zone 4 is expected. When maximum ice loads occur, the winds tend to be stronger in zone 1. The figures in Table 6 represent a 10% risk figure based on only a 10-year design lifetime.

Unlike the wind conditions, the maximum ice and wind combinations presented in Table 6 are not equally likely throughout each representative climatic zone. In zone 1, for example, the extremes contained in the table occur along the coast in the western portion of the region while near the Alaskan-Yukon border the maximum expected ice thicknesses have fallen to almost half of these values. A similar variation exists in zone 4, but the smallest maximum ice accumulation expected for any location in this area exceeds the worst case for zone 1. Careful consideration of the ice and wind conditions, perhaps leading to special designs for structures for zone 4, will be required to produce a system capable of surviving the severe environment which exists along the eastern coast of Canada.

TABLE 1

Climatic Zones for SEEK FROST

ZONE 1	Alaskan Coast
ZONE 2	Yukon Coast to Mackenzie River
ZONE 3	Mackenzie River to west of Cape Dyer, NWT
ZONE 4	Eastern Coast from Cape Dyer, NWT to southern Labrador

TABLE 2

Temperature Data

Climatic Zones

	1	2	3	4
Absolute Max Temp (°F)	80 (Wainwright)	93 (Aklavik)	87 (Coppermine)	99 (Goose Bay)
Range of Mean Monthly Max Temp (°F)	-14 (Feb) to 51 (Jul)	-10 (Jan) to 66 (Jul)	-17 (Feb) to 57 (Jul)	-14 (Feb) to 69 (Jul)
Range of Mean Monthly Min Temp (°F)	-28 (Feb) to 35 (Jul)	-26 (Jan) to 47 (Jul)	-39 (Feb) to 43 (Jul)	-25 (Feb) to 54 (Jul)
Absolute Min Temp (°F)	-59 (Barter Island)	-62 (Aklavik)	-63 (Cambridge Bay)	-51 (Fort Chimo)
Mean No. Days with Temp $\geq 90^{\circ}\text{F}$	0	0	0	0 (0.8 Goose Bay)
Mean No. Days with Temp $\leq 32^{\circ}\text{F}$	324	264	290	235
Mean No. Days with Temp $\leq 0^{\circ}\text{F}$	169	159	170	60 (120 Ft. Chimo to 18 Fox Run)

TABLE 3

Precipitation Data

Climatic Zones

	1	2	3	4
Max mean precip (In)	15.3 (Cape Lisburne)	9.0 (Akulavik)	10.0 (Clyde)	52.0 Harrington Harbor
Min mean precip (In)	4.5 (Pt Barrow)	6.5 (Bagnell Beach)	4.0 (Byron Bay)	13.3 Frobisher Bay
Max Mean Snowfall (In)	54.9 (Cape Lisburne)	47.1 (Akulavik)	69.4 (Clyde)	200 Cartwright/Har.Harbo.
Min Mean Snowfall (In)	28.3 (Pt. Barrow)	22.1 (Bagnell Beach)	21.4 (Gladman Pt)	56.0 Cape Hopes Advance
Mean No. days per year precip \geq 0.1 In	23	24	30	68
Mean No. days per year snowfall \geq 1.5 In	8	6	7	25
Mean No days per year thunderstorms	<1	1	<1	0 (northern) 5 (southern)

TABLE 4

Flying Weather

	Climatic Zone			
	1	2	3	4
Frequency of occurrence of ceiling < 1500 feet and/or visibility < 3 mi.	35% (50%-summer)	20% (35%-Autumn)	14-30% (60%-Autumn)	13-22% (35%-Variable)
Ceiling < 300 feet and/or visibility < 1 mi.	14% (25%-summer)	4% (10%-Autumn)	4-25% (48%-Autumn)	5% (13%-variable)

NOTE: Figures represent estimated means and extremes based on 3-hourly observations. The means reflect all such observations while the figures in parentheses represent an estimate of the mean of the worst periods.

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TABLE 5

Maximum Sustained Wind Speeds and Extreme Gusts

	Climatic Zone			
	1	2	3	4
Sustained wind (KT)	123	71	113	152
Peak gust (KT)	156	92	128	195

NOTE: Wind speeds are those encountered at 30 feet above the surface for a one percent risk of being equalled or exceeded at least once during a 20-year design life.

TABLE 6

Maximum Ice and Wind Loads

	Climatic Zone			
	1	2	3	4
Radius of ice (in.) around 0.5 inch radius wire:				
Rime Ice:	1.5	0.9	2.4	3.6
Clear Ice:	0.5	0.3	0.8	1.2
Thickness (in.) on a horizontal plate:				
Rime Ice:	1.8	1.5	2.4	3.3
Clear Ice:	0.6	0.5	0.8	1.1
Maximum wind (KT) with any ice load	75	53	57	95

NOTE: Dimensions of accumulated ice represent 10% risk values expected to be equalled or exceeded during a 10-year design lifetime.

OPERATION OF HELICOPTERS IN ICING ENVIRONMENT

Background

This paper deals with the experience of operating helicopters, particularly the Sikorsky S-61N, in offshore oil service in the North Sea under icing environment. It covers the climatic conditions permitted, the problems associated, the capabilities thus proven, and the plans for the future. In view of the growing need for more widespread operation in icing conditions, particularly for wintertime IFR operations offshore United States and Alaska, the plans for accomplishing this for both our S-61N and S-76 helicopters are treated.

Definition

The need for flight capability into icing weather conditions arose as soon as helicopters first demonstrated their capability to operate under IFR. In the latitude of the United States and Europe, without the capability to operate under icing environment, IFR operations become seriously handicapped, if not impossible, sometimes as early as September and as late as May. Fortunately, the greatest bulk of the commercial helicopter IFR experience was accumulated with our S-61 in the Los Angeles area where full IFR operation for the scheduled passenger airline transport category service was approved in March of 1966. Temperatures, however, in that area seldom reached freezing levels and, hence, the service was not handicapped by icing conditions. It was not until the IFR operations offshore in the North Sea became routine in 1969 that the need for operation in icing was faced as a sine qua non for a reliable service. It was fortunate, however, that three factors helped the S-61 as well as the British Wessex S-58 Gnome-powered helicopters to gain civil air-worthiness approval for operation in North Sea icing conditions.

1. The recognition that operation into only a small spectrum of the total possible icing environment in which fixed-wing aircraft are able to operate, would be a significant benefit because of certain peculiarities of helicopter operations over the North Sea. These involved the range of temperatures, which were relatively higher than normally encountered, the altitude flown which was lower, and the amount of humidity or moisture in the air, which was usually less.
2. The attitude of the British Civil Air-Worthiness Authorities, whose regulations permitted them to grant permission for helicopter operation into the above limited range of icing environment rather than requiring demonstration of capabilities to be able to handle the entire icing spectrum. The latter position has been held by the U.S. FAA and has thus far precluded any helicopters being granted permission by the FAA for operations into icing conditions.

3. The need for, and to the attitude of, the British helicopter operators who, based on limited encouraging experience, had the weather opportunities and were able to conduct trials and tests, to prove the S-61's capability to operate in "light icing" conditions to within certain temperature and altitude limits.

Experience Thus Gained

Since approval by the British U.K. in 1972, S-61N helicopters have accumulated an estimated 30,000 to 50,000 flight hours of operation in conditions where icing was likely to be encountered. Although icing was encountered only during some of those hours, it is nonetheless very significant, since without the capability and permission to handle icing, a considerable amount of flying would never have been possible. This icing experience to date has been without incident, except for a few cases of engine flame-out due to sudden release of accumulated snow. Further occurrences are not likely because of changes in operating procedures. Furthermore, it has imbued to all concerned a level of confidence that prompts them now to increase the permissible operating spectrum.

Scope of Operating Environment Presently Permitted

The S-61N helicopters in offshore oil services in the North Sea operate into icing conditions to within the following limits, as appearing in the British Airways Helicopter's S-61N flight manual, SA 4045-82, Amendment No. 9.

1. Flight in icing conditions must be confined to areas outside of controlled airspace.
2. The meteorological forecast shall not be more severe than "light icing".
3. Ambient temperature shall not be lower than -5°C .
4. Pressure altitudes shall not be greater than 5,000 feet.
5. Maximum take-off and landing weight for enroute altitudes not in excess of 5,000 feet pressure altitude shall be scheduled in accordance with Fig. 1.*
6. Maximum torque allowable in level flight shall be in accordance with Fig. 2. *
7. In descent, the maximum allowable airspeed shall be $V_{no}-10$ kts. (10 kts. less than normal cruise).

Equipment Required

In order to operate in the icing conditions, only the following equipment is required to be installed on the helicopters:

1. The Sikorsky-designed fiberglass engine air intake ice guard, also known as the Foreign Object Deflector (FOD) shield.
- * Refers to charts in British S-61N Flight Manual.

2. An ice detector, which is a cigar-size rod mounted crosswise to the air flow outside the cockpit and visible to the pilot.
3. A safety restraint on the long wire radio aerial, for redundancy of attachment.
4. An illuminated outside air temperature indicator.
5. Heated glass windshields.

Effect of Operation in Icing Conditions

The biggest single effect of operation in icing conditions is the accumulation of ice on the leading edges of the main rotor blades, which in turn deteriorates the air foil characteristics and, thus significantly increases the power required. A secondary factor is increased vibration due to the random and unequal main rotor blade ice accretion. In some of the initial trials, ice accumulation had a tendency to restrict flight control movements both in the main rotor head and the tail rotor head, but these are no longer a factor because protective covers were added to all S-61N aircraft. Aircraft weight increase is sometimes noticed, with less effects, as ice accumulates on innocuous parts, such as sponsons, landing gear struts, airspeed "rams horn" probes, stabilizer and fuselage. There have been a few cases of damage to the tail rotor leading edges which are assumed to have occurred due to striking pieces of ice shed from the main rotor blades, particularly during altitude changes, the final descent, or rotor shutdown.

Range of Operating Weather Needed

Because of its generally low altitude characteristics, the helicopter is not expected to require, at least until later designs are developed incorporating cabin pressurization, operation in icing above 10,000 feet. Even permission for altitudes as high as 5,000 feet would probably satisfy 90 percent of the requirements for the immediate future. Examining the world areas where helicopters operate, excluding Arctic winters, temperatures at these altitudes seldom go below -20°C . At lower altitudes, permission to operate as low as -8°C or -10°C would satisfy the vast majority of the immediate requirements. The British low temperature limit of -5°C is well supported by many flight hours in actual icing conditions.

Icing Conditions

The severest icing conditions that aircraft encounter are at altitudes between 10,000 and 20,000 feet. Helicopter flight in these conditions are, therefore, extremely remote. Liquid water content in icing conditions is measured in grams per cubic meter. "Severe icing" conditions are defined to have a water content of .8 or more grams per cubic meter. "Moderate icing" conditions have a liquid water content of .4 to .8 grams and "light icing" has .2 to .4 grams.

There are three other distinctions in icing weather and these concern the nature of the moisture, namely "freezing rain" or super-cooled water, snow and ice crystals. Another consideration is the amount of time at which the helicopter should be able to operate in any of the above conditions. This is key to any approval for operation in an icing environment, because the nature of the atmosphere is such that changing altitude by 1,000 or 2,000 feet can produce a change in temperature, icing condition, and sometimes the nature of the water content. Thus, while freezing rain is the most difficult, from the standpoint of operation, it does not necessarily become a design condition because a change in altitude can result in a non-icing environment. On the other hand, flight in "light icing" encountering water vapor as ice crystals is a requirement that can be handled for periods of up to one or two hours.

Ice crystals will adhere to parts of the helicopter, whereas snow found at lower altitude generally does not. However, snow remains more of a visibility problem. Again, this can be obviated by climbing to higher altitudes.

Performance Effect

Based on the initial trials, the British Airways Helicopters and the British Civil Aviation Authority have agreed to utilize different weight, altitude, and temperature curves for flight under icing conditions based on the ability to maintain the IFR-required single-engine performance of a rate of climb 150 foot per minute at 1,000 feet above take-off point or the minimum obstruction altitude. This curve represents approximately 1,000 pounds lower gross weight or 70 more required horsepower than would be permitted under IFR at the same temperature and altitude without icing being anticipated. However, because these temperatures are sufficiently colder than normally encountered throughout the rest of the year, it is perhaps more useful to say that under icing conditions at 4°C , the permissible operating gross weight is the same as would be permitted at 16°C without icing being a factor. Also, cruising speed is generally planned to be 10-15 knots slower, simply to reduce roughness for pilot and passenger comfort. Our S-76, which will meet IFR single-engine performance at its maximum gross weight, 9,700 lbs., up to 90°F (32°C), should still be able to maintain that same weight under icing conditions, even if it were to experience the same proportionate increase in power requirements as the S-61N under the same icing conditions.

This discussion does not have to consider the effect of icing on engine operation because in the certification of any powerplant installation either by the FAA or the British CAA, it is necessary to demonstrate that the engine is capable of operating in an icing and rain environment. Thus, all Sikorsky commercial helicopter models, commencing with piston engine models which had carburetor heat, and the turbine models which have either electrical or bleed air heated air intake bell mouths and oil or air-heated inlet guide vanes have had ice and rain protected engines. This allows operation in liquid water contents

as high as 2.0 gram per cubic meter. However, the water and ice content in these demonstrations was assumed to enter the engine exactly as it existed in the atmosphere rather than after accumulating on certain parts of the airframe as ice chunks before entering the engine. The engine manufacturers disclaim responsibility for this situation and refer to it as a foreign object ingestion problem. Unfortunately, some engines can be significantly damaged by a piece of ice as large as a lump of sugar. Hence, in helicopters early snow and ice experience disclosed numerous cases of engine damage (including flame-outs) due to snow or ice accumulation on the forward windshield or cockpit canopy, coming loose as chunks, and going into the engine. This has been precluded on the S-61 by the installation of the engine air intake shield.

Main Rotor Blade Effect

All of the approvals thus far have not considered special protection to the main rotor blade leading edge beyond the usual stainless steel abrasion strip. It was learned early in icing trials that because of the relatively high tip speed of helicopter rotor blades, that the temperature rise associated with the impingement of air on the leading edge, which is of the order of 2 to 3°C, is sufficient to negate any appreciable ice accumulation in the outer third of the blade. This also is aided by centrifugal force, although experience to date has shown that the ice accumulation on the remaining in-board section is sufficiently limited so that the approved operating envelopes can be achieved. It is realized that for significant increases in water vapor content, some form of heating of the in-board portion of the main rotor blade must be provided. The most encouraging system thus far has been electrical heating, which is already in operation on Royal Canadian Navy S-61 types. However, the size of the electrical power load is quite significant, in fact, usually two or three times the total electric power requirement of the helicopter, including that for windshields and engine air intakes.

A problem still to be resolved is the effect of runback ice formed by water melted by the electric heaters that travels to unheated portions of the blade. A successful method currently utilized to maintain acceptable levels of electrical load is a cycling technique whereby heat is applied to various sections of the blades intermittently. Thus, centrifugal force aids in shedding ice which has been allowed to build up during the temperature "off" period and then becomes freed when heat melts its bond at the surface. This is called "de-icing", as opposed to "anti-icing", which refers to the alternate practice of applying heat continuously at a rate that does not permit ice to form. The power required to accomplish anti-icing on helicopter main rotor blades is extremely high because of the large areas requiring heat. Anti-icing is used on windshields and air intakes, but is possible only because the areas involved are relatively small.

Status of FAA Approval for S-61

As mentioned above, the FAA requirement that any helicopter be able to demonstrate its capability to handle the full range of atmospheric icing conditions (the same as a fixed-wing aircraft) has precluded helicopter manufacturers from obtaining

approval for operation in icing. However, in light of the British CAA satisfactory experience, the U.S. manufacturers and operators may put pressure on the FAA to change from this position, at least for helicopters. An FAA program is currently being planned to utilize the British experience and to obtain initial approval for operation of the S-61N under icing conditions to approximately the same limits. Assuming the availability of an aircraft and the finding of suitable atmospheric conditions in the test area chosen, such could be accomplished by Spring of 1978. British pilots have kept accurate flight log records of every flight on which they expected or actually encountered icing conditions and these will be to supplement the FAA testing.

Position on the S-76

All of the foregoing information has been known and taken into consideration in the design of the S-76. Engine air intakes, therefore, will be qualified for operating in icing environment. Attention has been paid to detail design of areas forward of engine inlets to preclude projections which would allow ice to accumulate. Cockpit windshields can be completely heated to the point of being anti-iced. The main transmission has an unused drive pad suitable for a second alternating current generator. This would be more than sufficient for electrical heating requirements for icing, except for the main rotor blades.

It is anticipated that by the Summer of 1977, when the first S-76 operators will be firming their requirements for optional equipment, that the program to obtain icing approval on the S-76 will be finalized for management evaluation, and a decision can be made at that time to proceed.

The design fabrication, and certification test of selected equipment will require two to three years. The actual flight tests will probably require at least two winter periods. Hence, approval for icing operation could be expected in the 1980/1981 time period.

EJN:cac
28 March 1977

THE IFR HELICOPTER

- equipping it can be simple
- microwave landing systems will insure its efficiency

Microwave instrument landing systems are ideal for helicopter IFR operations / staff report / And they can be set up everywhere a copter can fly: in cities, at airports, in remote areas, at sea, etc.

reprinted from

rotor & wing

may/june 1973

Attachment 7

MICROWAVES. It's been alleged, are hazardous in home ovens, but they'll make flying a whole lot safer and more efficient when used in tomorrow's instrument landing systems.

Because of their advantages, the FAA has adopted a long-range plan to develop a full-fledged microwave system, or MLS, to replace conventional instrument landing systems, or ILS, and meet all civil and military needs until the year 2000.

Conventional ILS scribes an electronic pathway along which an aircraft glides to a runway as though it were rolling down a moderate incline. This path is delineated by radio beams transmitted from the runway area.

But conventional ILS has grown old and become obsolete. It also has some serious shortcomings, such as the frequencies at which the beams are transmitted. At times it is difficult and costly to install: The terrain off the end of the runway must be level for the "up-down" signals indicating the proper gliding angle to be accurate. In addition, ILS beams can be distorted by nearby terrain features and buildings.

ILS is not particularly suited to helicopter operations. Helicopters normally operate in remote, rugged areas, and at sea, using oil rigs or ships for helipads, and in congested urban centers, and sometimes at airports. Therefore they need a precision approach system that provides reasonably short, high glide paths that are air-selectable. A microwave landing system can meet those requirements.

One such system is called Co-Scan; it's built by Cutler-Hammer's AIL Division of Deer Park, Long Island, N.Y. It is a scanning-beam type system developed 15 years ago, and has been selected by the Canadian Ministry of Transport for use in that country's STOL demonstration program. Military versions of the system are in use by the U.S. Navy and the Royal Swedish Air Force; another version is being developed for the U.S. Army.

Two demonstrations for various government and industry officials were recently conducted involving a Co-Scan unit and an IFR-equipped helicopter. The first of these took place during the week of Jan. 15 at Dulles International

Airport, near Washington, D.C. The helicopter was a twin-turbine Bell 212 owned by the New York State Dept. of Environmental Conservation and piloted by Captains Charles F. Wolfe, Sr., chief pilot, engineering, and Donald E. Hamilton, senior conservation pilot. Also on board was a Butler RNAV system which provided integration of area navigation techniques with the Co-Scan MLS.

With the Co-Scan unit set up alongside the STOL runway at Dulles, Wolfe and Hamilton flew a number of instrument approaches on selected glidepaths of six and 12 degrees, after transitioning on to the unit's localizer from a waypoint set into the copter's RNAV unit. (A DHC-6 Twin Otter also participated in simultaneous demonstrations.)

Then on Feb. 7 Captains Wolfe and Hamilton,

flying the same aircraft, shot instrument approaches into New York City's West 30th St. Midtown Helipoint, again using glide angles of six degrees and more.

The results were effective, impressive, and pleasing to all. Referring to the demonstrations, Fred Pogust, head of AIL's Flight Guidance Systems Dept. said:

"This kind of complete landing service is to be expected of Co-Scan. The system was always conceived as being able to serve all branches of aviation and not be limited to use by a few operators. It was designed to be used at all locations by anything that can fly. We conclusively showed the practicality of approach paths keyed to the needs of the aircraft and the residents on the ground. We need no longer fly the single path dictated by the ILS, or any 'fixed-beam' microwave landing system."

The Co-Scan system consists of a small self-contained ground unit (about four feet high and weighing 160 lbs.) that can be placed without concern for most site features. Its narrow beams sweep by the aircraft's antenna and do not simultaneously reflect off surrounding surfaces. The received signal provides the exact azimuth and elevation

angle of the copter in relation to the ground station.

In addition to receiving, decoding, and displaying the steering commands, the receiver indicates to the pilot by warning flags on his instrument if any failure should occur in signal transmission. The receiver also includes built-in test equipment that allows the pilot to check out his receiver prior to each landing.

The MLS equipment permits a pilot to choose the glide slope by using a switch on the cockpit panel. (Present day ILS produces a single glide-slope angle, fixed at the time of installation of the ground equipment and all aircraft have to follow the same slope.) With pilot-selectable glide-slope angle, STOLs might choose a five- to six-degree slope, helicopters eight

or nine degrees — or up to 15 degrees if a special obstacle-clearance problem exists, all without adjustment on the ground.

The Co-Scan ground station's azimuth and elevation signals originate from a single point. Scanning motion is supplied by 360-degree rotation of both radome-enclosed antennas, which are mechanically linked. Transmission takes place only over the specified angles of coverage.

All components are enclosed in a single unit. Optional field monitors or



Microwave instrument

Staff Report

landing systems

are ideal for heli-

copter IFR operations



MLS

nonstandard batteries can be externally located, and space is provided for portable batteries or an AC power adapter, and for an optional DME transponder.

The equipment can have folding legs and all-terrain pads, or can be permanently anchored to a hard ground pad if desired.

The Co-Scan airborne equipment consists of a receiver/decoder unit and a control box. The receiver/decoder is packaged in a standard 1/2 ATR case and shock isolation mounts. The control box is designed for the standard five-inch control panel.

Co-Scan operates in a frequency band from 15.4 to 15.7 GHz by transmitting radio energy in the form of pairs of pulses. These pulses originate at the azimuth and elevation antennas in a sequence such that only one antenna is radiating at a time.

The antennas rotate at a rate of four times per second and are phased so that they can scan through their required coverage section during different time segments. The azimuth antenna radiates 20 degrees to the right and left of center for a total 40-degree coverage. The elevation antenna radiates from zero to 20 degrees.

The remainder of the 1/4-second time period can be used for DME transmissions on the same RF channel if the optional Ku-band DME is included in the system.

The equipment is capable of radiating on any one of 20 channels. These 20 channels are developed using 10 RF frequencies within the assigned band and two pulse-multiplex codes to double the number of channels.

The RF energy when radiated is in the form of a flat broad beam that scans through the coverage angle. The azimuth beam is three degrees in the horizontal dimension and about 20 degrees broad in the vertical plane. The elevation beam is two degrees in the vertical dimension and 40 degrees broad.

The pulse pairs transmitted during a scan cycle contain the information that the equipment sends to an airborne receiver. The spacing between pulses indicates the identity of data being transmitted (azimuth, elevation or DME) and also the channel multiplexing. The spacing between successive pairs indicates the pointing angle of the beam at the instant of transmission.

The spacing between pulse pairs when an antenna is pointing at zero degrees is 60 microseconds. The spacing changes by two microseconds for

every degree of travel of the beam. Thus, at a five-degree elevation angle, or five degrees from azimuth centerline, the spacing is 70 microseconds.

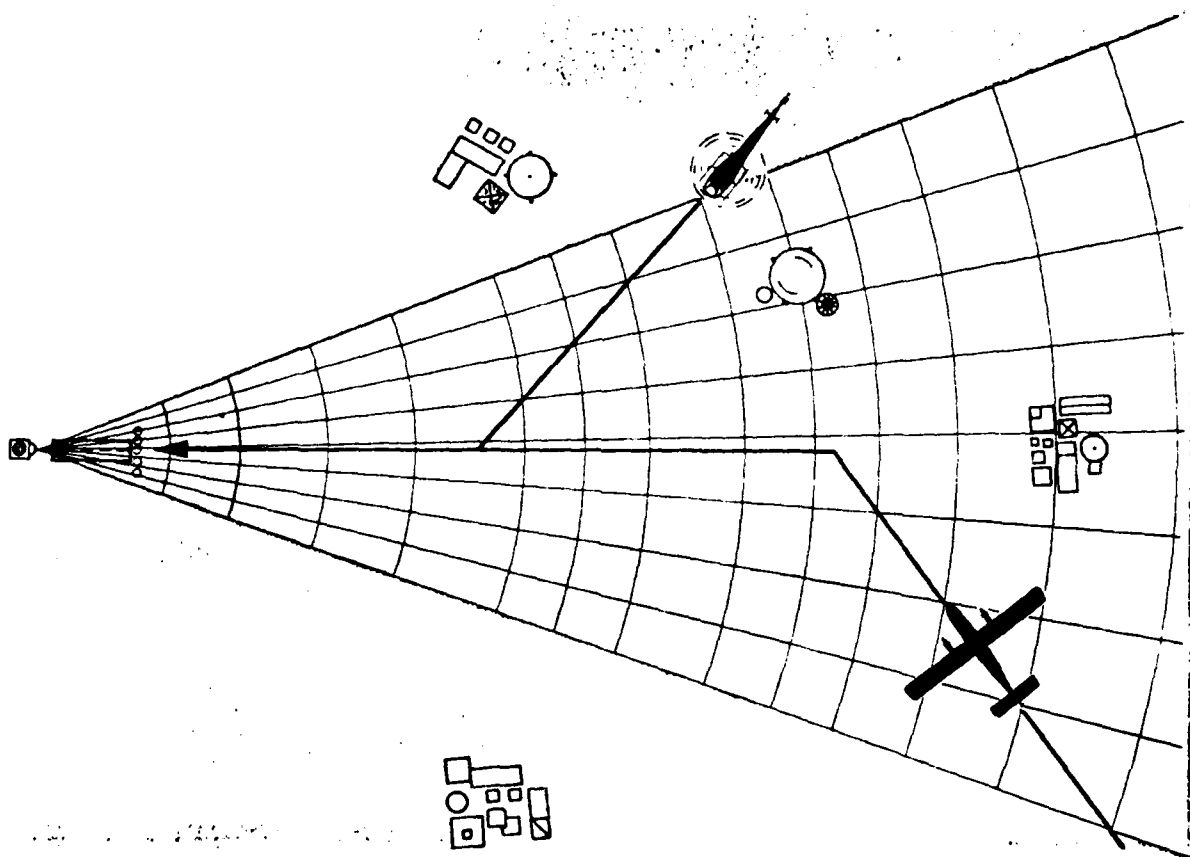
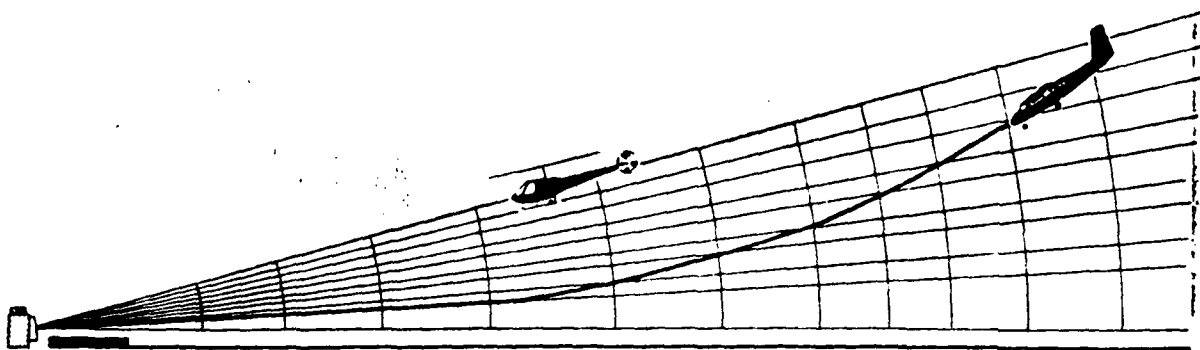
In the airborne set the control box provides selection of one of 20 channels, selection of glide-path angle, and a test feature. The receiver/decoder unit accepts the ground transmissions and converts them to the signals required to display deviation from the desired localizer and glide paths. These signals are compatible with standard Course Deviation Indicators, flight director systems or autopilot approach couplers.

Microwave instrument landing systems will eventually become the international standard, but the first installations might not come for five years. In the meantime, the FAA has announced its intention to select an "interim" MLS, such as the Co-Scan system.

MLS will be a boon to those concerned with IFR helicopter operations. According to some, the MLS is much easier to fly, especially for the copter pilot, mainly because it's a system that matches the helicopter's unique flight characteristics and allows it to take advantage of dogleg approaches and steep glide angles. Additionally, adoption of an interim MLS might help the FAA solve the "one-pilot/two-pilot" IFR helicopter problem, or at least establish more meaningful criteria.

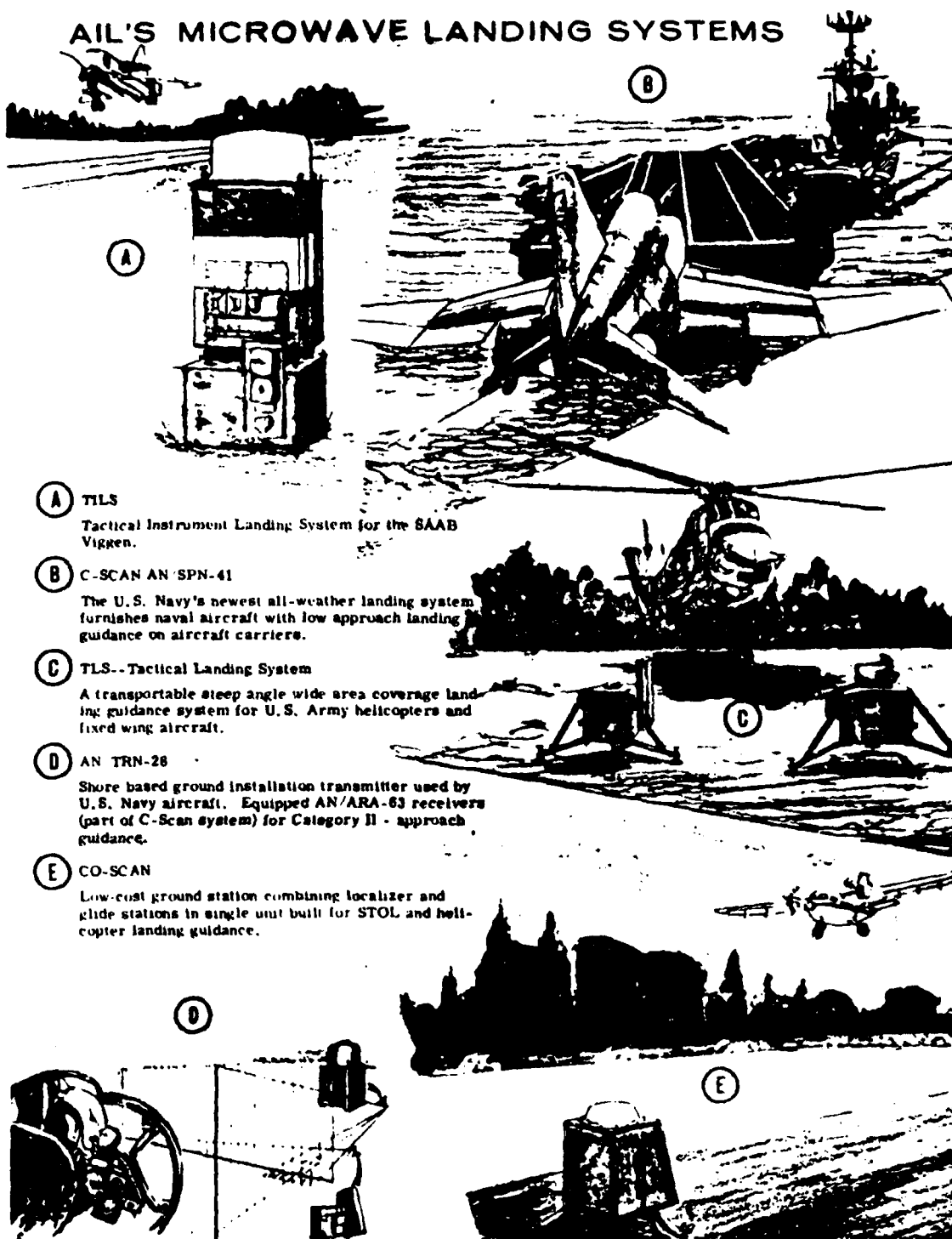
Currently, the FAA requires two pilots for civil IFR helicopter flight. The agency says that flying a helicopter under IFR conditions and monitoring a full instrument panel is too great a workload for only one pilot. However, the FAA has also offered to certify helicopters for one-pilot IFR operations on a case-by-case basis if each operator can demonstrate that such operations are practical. But helicopter manufacturers and operators reject this plan; they say it's too expensive. The manufacturers believe that cockpit workloads can be reduced significantly if the helicopter is equipped with a modern autopilot and a stability augmentation system, making it safe, efficient, and economical for one-pilot operation.

Microwave landing systems will figure significantly in this argument, especially if pilots, operators, government and industry representatives start expressing their experienced, informed opinions about building an intelligent plan for air traffic control and IFR helicopter operations. One way to do so is by writing *Rotor & Wing* with your comments and suggestions. We'll publish what we can and pass them all along to the right people within the FAA.



MLS approaches need not follow straight lines nor shallow glide-slope angles. With appropriate avionics, pilot can fly variety of dogleg approaches and also select any one of several glide-slope angles which will match aircraft's performance.

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(A) TILS

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(B) C-SCAN AN/SPN-41

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(C) TLS--Tactical Landing System

A transportable steep angle wide area coverage landing guidance system for U.S. Army helicopters and fixed wing aircraft.

(D) AN TRN-28

Shore based ground installation transmitter used by U.S. Navy aircraft. Equipped AN/ARA-63 receivers (part of C-Scan system) for Category II - approach guidance.

(E) CO-SCAN

Low-cost ground station combining localizer and glide stations in single unit built for STOL and helicopter landing guidance.

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c. Helicopter Support for Minimally Attended Radar Stations (SEF 10.139)

1. The utilization of HH-3 helicopters to support the minimally augmented radar stations listed within the SEER 16100 OLP is feasible and well within the operational capability of this unit. The HH-3s currently assigned to the theater could accomplish this mission without augmentation provided that all resupply items are prepositioned to strategically located FOL stations.

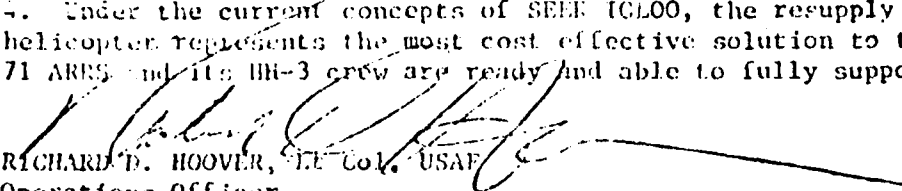
a. The envisioned 3000 pounds of resupply per month would require two flights per resupply point with an approximate load of 1500 pounds per flight. Any increase in the resupply level will require an adjustment in the number of flights per month to each site. The 1500 pound cargo load per flight will allow the helicopter to deploy from the FOL to the resupply point and return without enroute refueling. For efficiency of operations, all resupply items slated for delivery to the sites each month should be in place prior to deploying the helicopters to the FOL's.

c. Winter conditions in this theater present limiting factors in the form of adverse weather and decreased daylight. Although these factors affect helicopter operations and may require the helicopter to set at the FOL waiting a "break" in the weather, the mission can still be accomplished in a timely manner. During the summer months, the increased daylight will allow the helicopter crews to make multiple flights from the FOL to the radar station each day. In addition, the terrain between the FOL's and the resupply points is relatively flat and unobstructed. This will permit helicopter operations down to operational minimums and eliminate several of the problems with the 71 ARRS now experiences with its Sparrevohn support.

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3. The staging areas for Cape Romanof and Sparrevohn should be changed to Bethel and Elmendorf respectively. Bethel is located only 150 miles from Cape Romanof as opposed to King Salmon which is 370 mi from the same point. Bethel also has an active Air National Guard unit, and these facilities could be utilized for temporary storage of the resupply items each month. By using Bethel as opposed to King Salmon, the resupply to this station could be accomplished with 50 per cent fewer flying hours. The staging point for resupply to Sparrevohn should be changed to Elmendorf. As Elmendorf is the home station for the helicopter crews, TDY funds which would be expended for operations at King Salmon would be eliminated.

4. Under the current concepts of SEEF ICLOO, the resupply of these sites by helicopter represents the most cost effective solution to the problem. The 71 ARRS and its HH-3 crew are ready and able to fully support this operation.


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